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99200807.8 16 March 1999 (16.03.99) EP(71) Applicant (for all designated States except US): AKZO NOBEL  
N.V. [NL/NL]; Velperweg 76, NL-6824 BM Arnhem (NL).

(72) Inventors; and

(75) Inventors/Applicants (for US only): KJELLQVIST LIN-  
DELL, Ann, Kerstin, Birgitta [SE/SE]; Linneg 131,  
S-216 18 Malmö (SE). KRUIITHOF, Klaas, Jan, Hendrik  
[NL/NL]; Debussystraat 3, NL-3906 BK Veenendaal (NL).  
LANSBERGEN, Adrianus, Jozefus, Hendricus [NL/NL];  
Hogeweg 5, NL-6862 WV Oosterbeek (NL). KLAASEN,  
Robert, Paul [NL/NL]; Iseoplantsoen 26, NL-1060 PW  
Amsterdam (NL).(74) Agent: SCHALKWIJK, Pieter, Cornelis; Akzo Nobel N.V.,  
Intellectual Property Department (Dept. AIP), P.O. Box  
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(54) Title: RADIATION CURABLE COATING COMPOSITION COMPRISING A SECONDARY CURING AGENT

## (57) Abstract

The invention relates to a radiation curable coating composition, which is formed by mixing (A) a radiation curable lacquer comprising a compound having an olefinically unsaturated double bond with (B) a compound comprising an electron donor-functional group capable of reacting with the compound, which is present in lacquer (A) having an olefinically unsaturated double bond, in the absence of electromagnetic radiation having a wavelength  $\lambda \leq 500$  nm. Compound (B) further can comprise a radiation curable-functional group. The invention also relates to a process for coating substrates using the radiation curable coating composition.

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RADIATION CURABLE COATING COMPOSITION COMPRISING A SECONDARY CURING  
AGENT

The present invention relates to a radiation curable coating composition  
5 comprising a secondary curing agent.

Such a composition is known, e.g., from US 4,128,600, wherein a radiation  
curable coating composition is disclosed which comprises a saturated polyol  
and a reactive oligomer selected from the group consisting of fully substituted  
10 poly(meth)acrylates of poly-functional alcohols. This known composition  
additionally comprises a polyisocyanate.

A primary concern in the coating industry is the need to reduce the emission of  
volatile hydrocarbons into the air.

15 In classic heat curing coating compositions a high-viscous film forming resin is  
mixed with a solvent to aid the manufacture of the coating composition and to  
facilitate the application of these compositions to substrates. During curing of  
the coating the solvent is driven off by the thermal energy used to effect the  
curing. A considerable amount of thermal energy is thus used to drive off the  
20 solvent. However, the thermal energy may cause considerable side effects in  
the coating or on the substrate, in particular when the substrate is heat  
sensitive.

To solve this problem, it was suggested to use a radiation sensitive reactive  
solvent to reduce the viscosity of the film forming resin. Upon radiation, these  
25 reactive solvents react with each other or with the film forming resin and a  
coating of good quality can be obtained. Optionally, the composition may  
comprise a crosslinker which reacts with the film forming resin.

A problem with these coatings on porous substrates is the penetration of the  
30 coating composition into the pores, in particular when radiation is used to cure

the coating. Since the radiation does not reach these areas, uncured coating material is the result. This can give health, safety, and environmental problems, e.g., when the substrate is cut or sanded. These problems occur even years after the lacquer has been applied. The same problems can be found in other  
5 substrates comprising shadow areas, e.g. in 3-D substrates, or when a pigmented lacquer is used.

In particular low-molecular weight material, viz. monomers and oligomers which are used as reactive oligomers, gives the biggest problem with penetration.  
10 Well-known acrylic diluents, e.g., tripropylene glycol diacrylate (TPGDA), hexanediol diacrylate (HDDA), and hydroxyethyl methacrylate (HEMA) are irritant and sensitising and will never react if they are not reached by the UV light.

15 To overcome the problems caused by the not yet reacted diluent, it is known in the art to add a secondary curing agent. In general, a secondary curing agent will have a lower reactivity towards the main film forming component(s) than the primary curing agent.

A well-known side effect of the addition of a secondary curing agent to a  
20 radiation curable composition is a reduction of the pot life of the thus obtained coating composition, since the secondary curing agent will also react in the absence of radiation.

(Poly)isocyanates are often used as a secondary curing agent if the lacquer is formulated in such a way that only OH-functional acrylic reactive oligomers are  
25 used, for instance HEMA. However, the use of isocyanates is not attractive and it limits the formulation possibilities of the lacquer.

Peroxy curing is not preferred, mainly due to handling problems such as short pot life.

In the market nowadays lacquer compositions comprising a carboxy compound  
30 and an epoxy secondary curing agent can be found. A major drawback of this

coating formulation is the required balance between reactivity and coating performance. With these systems a fair coating performance can only be obtained after long reaction times. If accelerators for the reaction are incorporated into the formulation, a poor coating performance is observed.

- 5    Moisture curing silanes can also be used as secondary curing agents but require controlled amounts of water to cure. In practice such a controlled environment is often hard to maintain.

DE 33 06 093 discloses a radiation curable binder emulsion prepared by  
10    reacting a secondary amine with part of the ethylenically unsaturated double bonds of a polymeric material. In this reaction, the secondary amine is not a secondary curing agent. Further, the mixing of a radiation curable lacquer having unsaturated double bonds with a compound comprising an electron donor-functional group is not mentioned.

- 15    EP 0 447 945 discloses the preparation of an amine modified urethane acrylate binder. In this reaction, the amine compound is reacted with an unsaturated double bond in the urethane acrylate binder. This reaction is one of the steps in the preparation of a radiation curable coating composition. In this reaction, the secondary amine is not a secondary curing agent. Further, the mixing of a  
20    radiation curable lacquer having unsaturated double bonds with a compound comprising an electron donor-functional group is not mentioned.

The present invention relates to a radiation curable coating composition which presents a solution to the above-mentioned problems, viz. a radiation curable  
25    coating composition which is obtained by mixing (A) a radiation curable lacquer comprising a compound having an olefinically unsaturated double bond with (B) a compound comprising an electron donor-functional group capable of reacting with the compound, which is present in lacquer (A) having an olefinically unsaturated double bond, in the absence of electromagnetic radiation having a  
30    wavelength  $\lambda \leq 500$  nm.

It was found that a broad range of radiation curable lacquers comprising unsaturated polymer resins, optionally including reactive oligomers, and compounds comprising an electron donor-functional group can be used in the composition according to the present invention.

The amount of compound B (i.e. the compound comprising an electron donor-functional group) that is mixed with the radiation curable lacquer should be such that a balance is found between the reactivity of the electron donor-functional group towards the radiation curable lacquer and the stability of the coating composition. In general, good results are obtained when 1 - 20 pbw of compound B are mixed with 100 pbw of the radiation curable lacquer composition A.

Within the framework of the present invention, a radiation curable coating composition is a coating composition which is cured by using electromagnetic radiation having a wavelength  $\lambda \leq 500$  nm. Examples of electromagnetic radiation having a wavelength  $\lambda \leq 500$  nm are, e.g., UV radiation or electron beam radiation.

Within the framework of the present invention the radiation curable lacquer (A) is a coating composition that is capable of curing and film forming without the necessity to add any further components and that will provide a coating with good properties, albeit that the cured coating then may comprise unreacted monomers and/or oligomers.

Preference is given to the use of a lacquer comprising UV curing unsaturated polymer resins, such as UV curable unsaturated polyester resins, UV curable unsaturated epoxy resins, UV curable unsaturated urethane resins, and UV curable unsaturated acrylic resins or mixtures thereof.

Examples of unsaturated polymer resins that can be used in the coating composition according to the present invention are Laromer<sup>®</sup> 8799 (ex BASF) Craynor<sup>®</sup> 104 (ex Cray Valley), Ebercryl<sup>®</sup> 210 (ex UCB), Crodamer<sup>®</sup> UVE 150 (ex Croda) or Actilane<sup>®</sup> 578 (ex Akcros).

5

To obtain a suitable application viscosity of the coatings, well-known UV curable monomers can be added as viscosity reducing agents and reactive oligomers. Examples of these reactive oligomers are tripropylene glycol diacrylate (TPGDA), hexanediol diacrylate (HDDA), and hydroxyethyl methacrylate (HEMA).

10

Good results are obtained when the compound comprising an electron donor-functional group is an amine- or thio-functional compound.

If an amine compound is used as compound comprising an electron donor-functional group, special attention should be paid to the reactivity of the amine compound towards the radiation curable lacquer. In general, primary amine compounds show a high reactivity towards unsaturated double bonds, leading to a relatively short pot life. The reactivity can be decreased by sterically hindering, shielding or capping the primary amine group.

In general, good results are obtained when the amine-functional compound is a secondary amine compound. These compounds show a very good balance between reactivity and stability. Examples of amine-functional compounds which give very good results in the coating composition according to the present invention are aminoethyl ethanolamine, aminoethyl piperazine,  $\alpha,\omega$ -diaminopropylene glycol (Jeffamine D400), diethylene triamine, dipropylene triamine, trimethylhexane(1,6)diamine (mixture of 2,2,4 and 2,4,4 isomers), and 3-aminopropyltriethoxysilane (Dynasil AMEO-T ex Hüls).

20  
25

Examples of thio-functional compounds that can be used in the coating composition according to the present invention are the esters of thioglycolic

30

acid, 1-mercaptopropionic acid or 2-mercaptopropionic acid with polyols, such as glycols, pentaerythritol, di-pentaerythritol, and trimethylol propane. Specific examples of suitable thiols are ethylene glycol bis (thioglycolate), ethylene glycol bis (2-mercaptopropionate), pentaerythritol tetrakis (thioglycolate), and pentaerythritol tetrakis (3-mercapto propionate).

Due to the presence of a compound comprising an electron donor-functional group capable of reacting in the absence of radiation with the compound having an olefinically unsaturated double bond in the coating composition according to the present invention, a secondary curing mechanism occurs which reduces the amount of uncured reactive species. This can be shown by several well-known analytical techniques, e.g., by extraction analysis.

If the electron donor-functional group is an amine- or thio-functional group, the compound comprising such groups undergoes a Pseudo Michael Addition (PMA) to the unreacted  $c=c$  bonds which are present in the lacquer composition. The double bonds not cured by the UV light will then be cured by PMA. In principle, there is no limitation of the formulation possibilities.

In general, the reaction between the electron donor-functional group and the unsaturated double bond will start when components (A) and (B) are mixed.

When the electron donor-functional group is an amine- or thio-functional group, in particular when the amine-functional group is a secondary amine group, a very good balance is obtained between the stability of the coating formulation and its reactivity. Without any special precautions, with these compositions a pot life between 6 and 8 hours can be obtained.

To further improve the film properties of the coating composition according to the present invention, a radiation curable group can be incorporated into the compound comprising an electron donor-functional group. Particularly good results can be obtained if the radiation curable group is incorporated by



reacting a so-called bulky unsaturated monomer with the compound comprising the electron donor-functional group. For example, by reacting DCPA (dicyclopentenyl acrylate, i.e. a bulky unsaturated monomer) with DETA (diethylenetriamine) or DPTA (dipropylenetriamine) an amine-functional  
5 electron donor compound is obtained with two UV curable groups, viz. the two dicyclopentenyl groups. This so-called dual-cure amine-functional compound can react with the unreacted c=c bonds which are present in the coating composition and can play a role in the curing of the coating when the coating is irradiated by actinic rays.

10

It was found that the radiation reactivity of the coating compositions according to the present invention is improved in comparison to known radiation curable coating compositions.

Further, with the composition according to the present invention, an improved  
15 through-cure and adhesion to the substrate was found in comparison to similar known coating compositions.

In addition, it was found that also the abrasion resistance of the coating compositions according to the present invention is improved in comparison to known radiation curable coating compositions, for example radiation curable  
20 lacquers comprising a compound having an olefinically unsaturated double bond but which do not contain a compound comprising an electron donor-functional group capable of reacting with the compound, which is present in lacquer (A) having an olefinically unsaturated double bond.

25 The coating compositions according to the present invention are particularly suited to be used as a radiation curable coating for substrates comprising shadow areas, such as 3D substrates or porous substrates like paper, wood or MDF, but they can also be used for the coating of metal or plastic substrates. Further, the coating compositions according to the present invention are very

well suited to be used in (heavily) pigmented radiation curable coating compositions.

Additives and fillers that are known to those skilled in the art can be added to the coating compositions according to the present invention, e.g., diluents, defoamers, levelling agents, antisetling agents, photoinitiators, rheology modifiers, and pigments.

The invention will be elucidated with reference to the following examples. These are intended to illustrate the invention but are not to be construed as limiting in any manner the scope thereof.

### Examples

#### Example 1

An abrasion resistant UV curable basecoat is prepared by combining 61 parts by weight of an polyester acrylate binder, 30 parts by weight of an acrylic diluent (25,3 parts by weight of which are tripropylene glycol diacrylate [TPGDA]), and 9 parts by weight of other components such as photoinitiators, defoamers, levelling agents, and fillers.

#### Example 2

A UV curable basecoat for furniture is prepared by combining 34,6 parts by weight of a polyester acrylate binder, 44,8 parts by weight of a polyether acrylate binder, and 17 parts by weight of other components such as photoinitiators, defoamers, levelling agents, and fillers.

#### Example 3

Several amine-functional resins are prepared on the basis of an acrylate and a secondary amine. Optionally TPGDA is added. The resins are prepared by

slowly adding the acrylate (DCPA: dicyclopentenylacrylate) to the amine. When TPGDA is added, it is added before the acrylate. The obtained mixture is cooled with ice/water in order to keep the temperature below 15°C. Approximately one hour after the addition, the reaction is completed. This can  
 5 be checked by Proton NMR on acrylic protons, which should no longer be present. The following amine-functional resins were prepared:

| Resin no. | Type of amine | Molar ratio<br>amine/DCPA/TPGDA |
|-----------|---------------|---------------------------------|
| 3a        | AEEA          | 1:1                             |
| 3b        | AEEA          | 1:1,25                          |
| 3c        | AEEA          | 1:1,5                           |
| 3d        | AEP           | 1:1                             |
| 3e        | DETA          | 4:5:1,5                         |
| 3f        | DPTA          | 4:5:1,5                         |
| 3g        | TMHDA         | 4:5:1,5                         |

Wherein

- 10 AEEA stands for aminoethyl ethanolamine  
 AEP stands for aminoethyl piperazine  
 DETA stands for diethylene triamine  
 DPTA stands for dipropylene triamine  
 15 TMHDA stands for trimethylhexane(1,6)diamine (mixture of 2,2,4 and 2,4,4 isomers)

For comparison, a solution was prepared of 70 wt.% Desmodur N (a polyisocyanate) in 30 wt.% ethylacetate. In the following, this resin is indicated as resin 3h.

20

#### Example 4

The curing time of some lacquer compositions was measured using a transport belt and a 80 W/cm<sup>2</sup> Hg lamp. The lacquer was applied to a substrate that was placed on the belt. The substrate was passed under the Hg lamp. The speed of

the belt was adjusted to get a fully cured lacquer after one passage under the lamp. The higher the belt speed, the shorter the curing time of the lacquer. In this way the effect of the addition of some resins of Example 3 on the reactivity of the lacquer of Example 1 was measured.

5

| Lacquer composition               | Belt speed<br>(m/min) |
|-----------------------------------|-----------------------|
| Example 1                         | 7                     |
| Example 1 + 6,45 wt.% of resin 3a | > 25                  |
| Example 1 + 6,45 wt.% of resin 3b | 23                    |
| Example 1 + 6,45 wt.% of resin 3c | 20                    |
| Example 1 + 6,45 wt.% of resin 3d | 23                    |
| Example 1 + 6,45 wt.% of resin 3e | 19                    |
| Example 1 + 6,45 wt.% of resin 3f | 22                    |
| Example 1 + 6,45 wt.% of resin 3g | 13                    |
| Example 1 + 6,45 wt.% of resin 3h | 8                     |

#### Example 5

Some resins of Example 3 are added to the lacquer of Example 1. The resulting  
10 lacquer is applied with a roller on oak parquet panels at 25-30 g/cm<sup>2</sup> and  
precured using Hg lamps with 80 W/cm<sup>2</sup> on a belt at a speed of 10 m/min. A  
second lacquer layer is applied at 25-30 g/cm<sup>2</sup> and cured at 5 m/min.

The amount of acrylic diluent in the obtained lacquer layer is determined by  
peeling 1 dm<sup>2</sup> with a depth of 2-3 mm off the panels and extraction with  
15 dichloromethane followed by gaschromatographic measurements (GC/FID). In  
this way the total amount of acrylic diluents in the lacquer is measured.

The following results are found:

| Lacquer composition               | Acrylic diluents<br>mg/dm <sup>2</sup> |
|-----------------------------------|----------------------------------------|
| Example 1                         | 14                                     |
| Example 1 + 6,45 wt.% of resin 3a | 9,5                                    |
| Example 1 + 6,45 wt.% of resin 3b | 7                                      |
| Example 1 + 6,45 wt.% of resin 3c | 7                                      |
| Example 1 + 6,45 wt.% of resin 3d | 7                                      |
| Example 1 + 10,0 wt.% of resin 3e | 10                                     |
| Example 1 + 10,0 wt.% of resin 3f | 7                                      |
| Example 1 + 10,0 wt.% of resin 3g | 10                                     |
| Example 1 + 9,2 wt.% of resin 3h  | 12,5                                   |

#### Example 6

- 5 Example 5 is repeated using the lacquer of Example 2. This lacquer is applied on MDF substrates.

The following results are found:

| Lacquer composition               | Acrylic diluents<br>mg/dm <sup>2</sup> |
|-----------------------------------|----------------------------------------|
| Example 2                         | 5,5                                    |
| Example 2 + 10,0 wt.% of resin 3a | 2,9                                    |
| Example 2 + 10,0 wt.% of resin 3b | 1,1                                    |
| Example 2 + 10,0 wt.% of resin 3e | 2,6                                    |
| Example 2 + 10,0 wt.% of resin 3f | 2,7                                    |
| Example 2 + 10,0 wt.% of resin 3h | 4,2                                    |

**Example 7**

The abrasion resistance of panels prepared according to Example 5 is measured using the falling sand method SIS 923509.

The following results are found:

5

| Lacquer composition               | Abrasion<br>mg/100 rev. |
|-----------------------------------|-------------------------|
| Example 1                         | 5,2                     |
| Example 1 + 10,0 wt.% of resin 3a | 1,5                     |
| Example 1 + 10,0 wt.% of resin 3d | 1,5                     |
| Example 1 + 10,0 wt.% of resin 3e | 1,7                     |
| Example 1 + 10,0 wt.% of resin 3g | 1,7                     |
| Example 1 + 9,2 wt.% of resin 3h  | 2,6                     |

## Claims

1. Radiation curable coating composition which is formed by mixing (A) a radiation curable lacquer comprising a compound having an olefinically unsaturated double bond with (B) a compound comprising an electron donor-functional group capable of reacting with the compound, which is present in lacquer (A) having an olefinically unsaturated double bond, in the absence of electromagnetic radiation having a wavelength  $\lambda \leq 500$  nm.
2. Radiation curable coating composition according to claim 1, characterised in that the compound comprising the electron donor-functional group is an amine- or thio-functional compound.
3. Radiation curable coating composition according to claim 1, characterised in that the amine-functional compound is a secondary amine compound.
4. Radiation curable coating composition according to claims 1-3, characterised in that compound (B) also incorporates a radiation curable-functional group.
5. Process for coating a substrate with a radiation curable coating composition wherein prior to application to the substrate the composition is formed by mixing (A) a radiation curable lacquer comprising a compound having an olefinically unsaturated double bond with (B) a compound comprising an electron donor-functional group capable of reacting with the compound, which is present in lacquer (A) having an olefinically unsaturated double bond, in the absence of electromagnetic radiation having a wavelength  $\lambda \leq 500$  nm.

6. Process according to claim 5, characterised in that the compound comprising the electron donor-functional group is an amine- or thio-functional compound.

5 7. Process according to claim 5, characterised in that the amine-functional compound is a secondary amine compound.

8. Process according to any one of claims 5 - 7, characterised in that compound (B) also incorporates a radiation curable-functional group.

10

9. Process according to any one of claims 5-8, characterised in that the substrate is a substrate comprising shadow areas.

15

10. Use of the coating composition according to any one of claims 1 to 4 for the coating of substrates comprising shadow areas.